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Satellite estimates of urban development for hydrological modelling

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ABSTRACT

We investigate the applicability of medium resolution Landsat satellite imagery for mapping temporal changes in urban land cover in European cities for direct use in urban flood models. The overarching aim is to provide accurate and cost- and resource-efficient quantification of temporal changes in risk towards the impacts of pluvial flooding. The results show that satellite imagery may have considerable potential in this respect, and that Landsat imagery can be used to provide accurate information on recent urban development patterns.

INTRODUCTION

Changes in the quantity and location of impermeable surfaces (IS) have important implications for the hydrological response during high intensity rainfall events. However, as urban land-use is characterised by a large degree of heterogeneity it is often problematic to categorise and map urban structure and development accurately at the desired scale (Dams et al., 2013).

Satellite imagery and remote sensing techniques offer a complete spatial and temporal coverage of urban land cover changes during the past 30-40 years. Medium resolution imagery provides the necessary spatial resolution and temporal coverage for analysis of small scale urban land cover changes, including variations in IS. Utilising satellite imagery in pluvial flood modelling allows for systematic investigations of the relationship between urban land cover changes and changes in risk towards the occurrence and impacts of urban flooding (Weng, 2012).

URBAN DEVELOPMENT MAPPING

Urban environments are highly dominated by impervious surfaces, as road infrastructure, buildings and other paved areas occupy a predominant share of the urban land area (Weng, 2008). For this reason changes in impervious surfaces can be used as an indicator of urban development. The impervious surface analysis is based on the notion of a near linear inverse relationship between vegetation cover and impervious surfaces in urban environments (Bauer et al, 2007). Most remote sensing estimates of vegetation are based on some measure of 'greenness', utilising the difference in reflectance between vegetated and non-vegetated areas.

Green vegetation has been found to reflect a much larger proportion of the incoming radiation in the near infrared wavelengths than in the red wavelengths (Jensen, 2007). This difference in reflectivity/absorption forms the basis for monitoring vegetation cover through the use of satellite imagery. For the current analysis the Normalized Difference Vegetation Index (NDVI) has been applied as a proxy for vegetation cover.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

In order to be able to estimate historical changes in impervious land cover using Landsat imagery regression models relating Landsat 8 NDVI values and % impervious land cover from high resolution aerial photography have been developed for eight European cities (Figure 1-2) The regression models can then be applied on historical Landsat images, which enables the quantification of temporal changes in urban land cover (Figure 2).

STUDY AREA

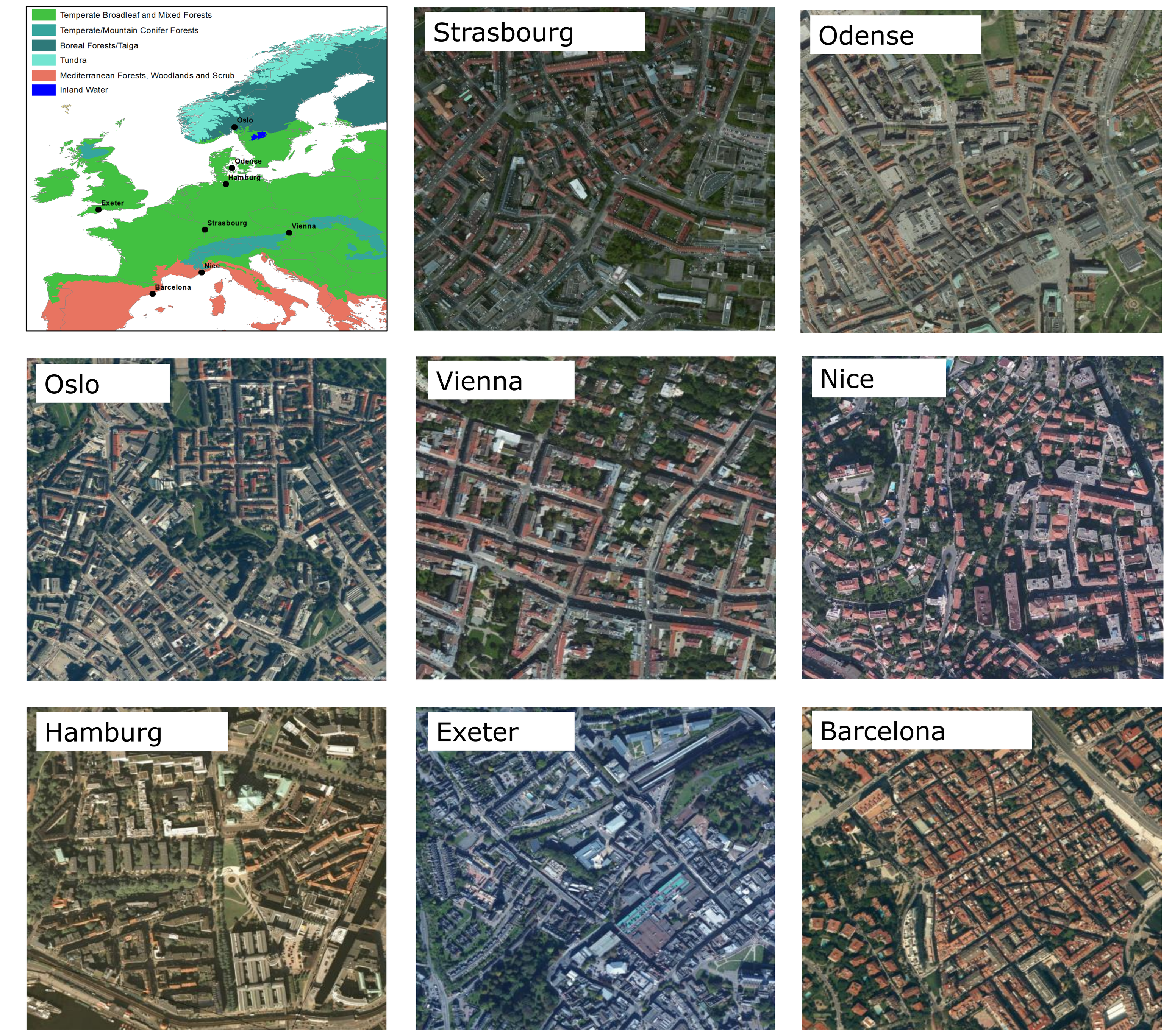

Figure 1: Locations and sub-areas of cities included in the study

DATA, METHOD AND RESULTS

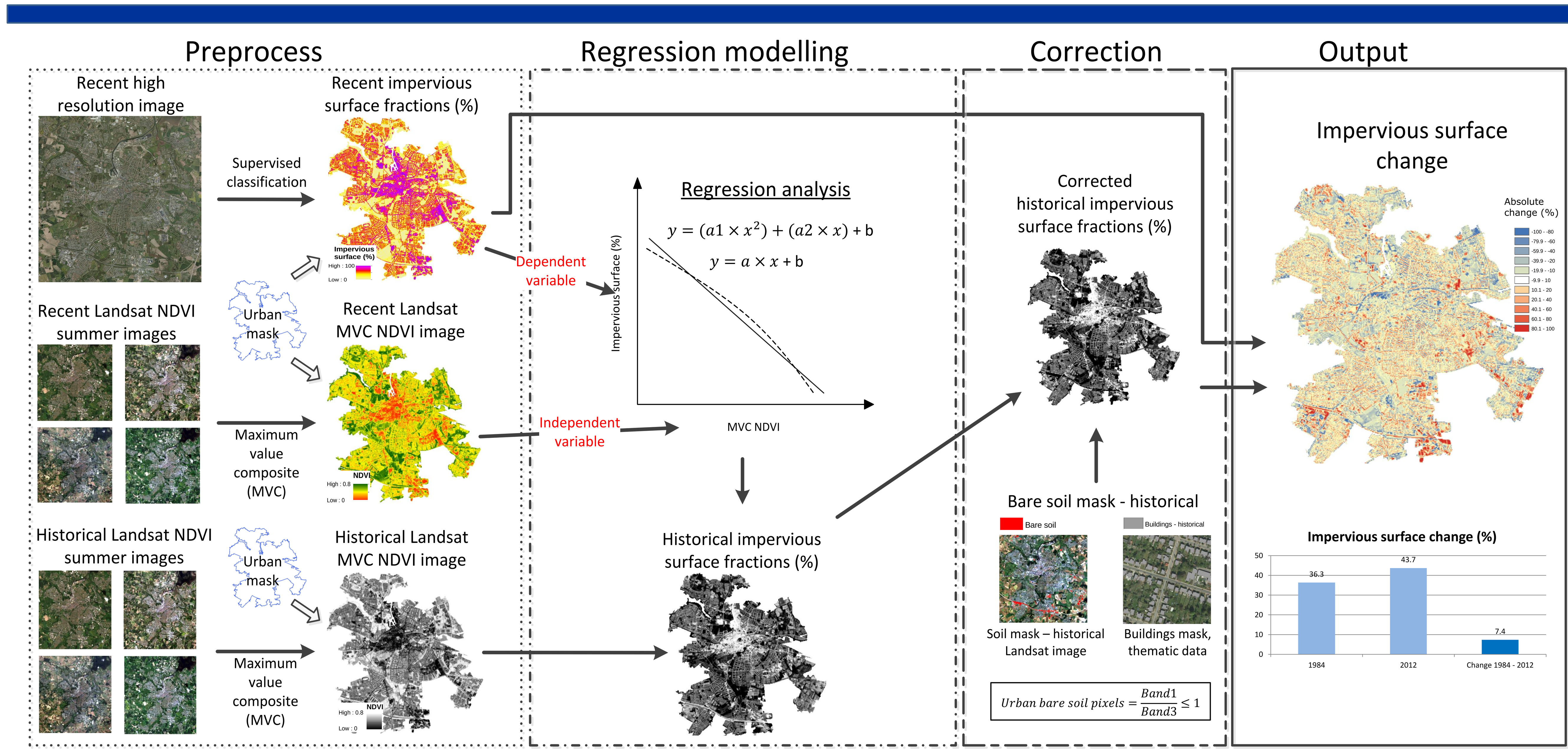

Figure 2:Methodology for estimating changes in impervious surfaces using Landsat satellite imagery

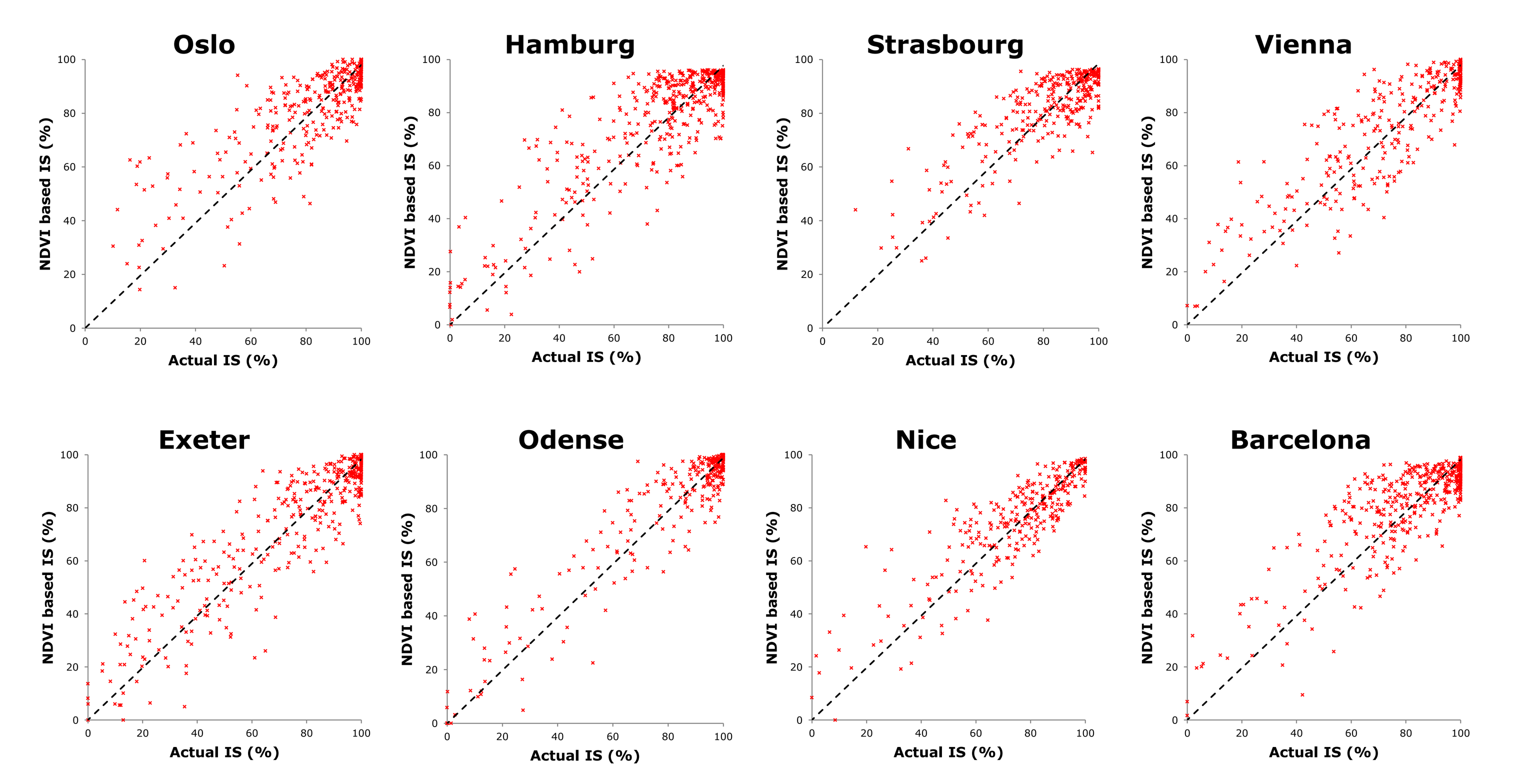

Figure 3: Relationship between Landsat based IS and actual IS

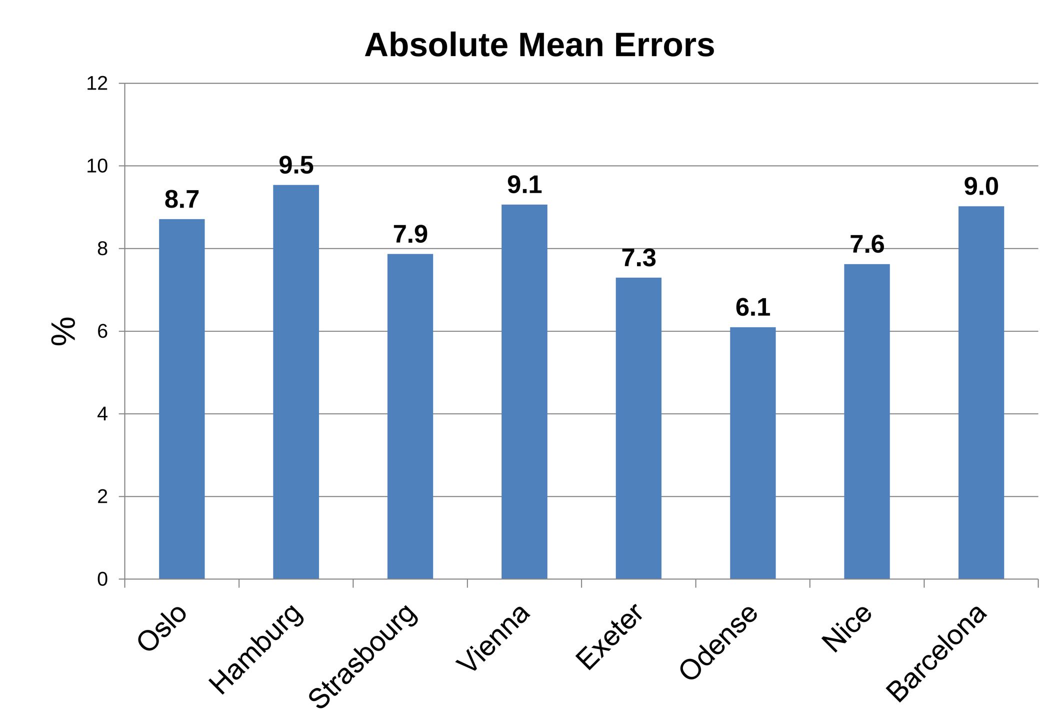

Figure 4: Accuracy assessment, Absolute mean errors (AME) of the Landsat based method

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